

OBJECT REGION DATA DESCRIBING METHOD AND OBJECT REGION
DATA CREATING APPARATUS

5 This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2000-138571, filed May 11, 2000, the entire contents of which are incorporated herein by reference.

The present invention relates to an object region data describing method of describing information about the object region in a video and an object region data creating apparatus.

Hyper media are configured such that related information called a hyper link is given in between mediums, such as videos, sounds or texts, to permit mutual reference. When videos are mainly used, related information has been provided for each object which appears in the video. When the object is specified, related information (text information or the like) is displayed. The foregoing structure is a representative example of the hyper media. The object in the video is expressed by a frame number or a time stamp of the video, and information for identifying a region in the video which are recorded in video data or recorded as individual data.

Mask images have frequently been used as means for identifying a region in a video. The mask image is a bit map image constituted by giving different pixel values between the inside portion of an identified region and the outside portion of the same. A simplest method has an arrangement that a pixel value of "1" is given to the inside portion of the region and "0" is given to the outside portion of the same.

Alternatively, α values which are employed in computer graphics are sometimes employed. Since the α value is usually able to express 256 levels of gray, a portion of the levels is used. The inside portion of the specified region is expressed as 255, while the outside portion of the same is expressed as 0. The latter image is called an α map. When the regions in the image are expressed by the mask images, determination whether or not a pixel in a frame is included in the specified region can easily be made by reading the value of the pixel of the mask image and by determining whether the value is 0 or 255. The mask image has freedom with which a region can be expressed regardless of the shape of the region and even a discontinuous region can be expressed. The mask image must have pixels, the size of which is the same as the size of the original image. Thus, there arises a problem in that the quantity of data cannot be reduced.

To reduce the quantity of data of the mask image,

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the mask image is frequently compressed. When the mask image is a binary mask image constituted by 0 and 1, a process of a binary image can be performed. Therefore, the compression method employed in facsimile machines or the like is frequently employed. In the case of MPEG-4 in which ISO/IEC MPEG (Moving Picture Experts Group) has been standardized, an arbitrary shape coding method is employed in which the mask image constituted by 0 and 1 and the mask image using the α value are compressed. The foregoing compression method is a method using motion compensation and capable of improving compression efficiency. On the other hand, complex compression and decoding processes are required.

To express a region in a video, the mask image or the compressed mask image has usually been employed. However, data for identifying a region is required to permit easy and quick extraction, to be reduced in quantity and to permit easy handling. Stated another way, the mask image is not suitable for identifying the object region in the video since it has a large quantity of data. The compressed mask image has a drawback in that coding/decoding is complicated and directly accessing to the pixel of a predetermined frame cannot be performed causing handling to become difficult.

Furthermore, only the positional information about

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the object region is represented and information about depth is not given. It is impossible to represent a state where the object disappears temporarily behind a thing. When shooting is done while the camera is following the moving object, the actual motion of the object is not represented. Thus, it is difficult to make a search, taking into account information about depth, disappearance behind another thing occlusion, and the movement of the camera. Therefore, in searching, all the things including unrelated ones must be processed.

BRIEF SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to method and apparatus that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

In accordance with the purpose of the invention, as embodied and broadly described, the invention is directed to an object region data describing method and an object region data creating apparatus which enable the region of a desired object in an image to be described in a small amount of data and facilitate the creation and handling of the data.

Another object of the invention is to provide an object region data describing method and an object region data creating apparatus which enable an object in an image to be searched for efficiently and

effectively.

According to embodiments of the present invention, there is provided a method of describing object region data about an object in video data over a plurality of frames, the method comprising:

approximating the object using a figure for each of the frames;

extracting a plurality of points representing the figure for each of the frames;

approximating trajectories with functions, the trajectories being obtained by arranging, in the frames advancing direction, position data about one of the plurality of points and relative position data about remaining points with reference to the one of the plurality of points; and

describing the object region data using the functions.

According to embodiments of the present invention, there is provided another method of describing object region data about an object in video data over a plurality of frames, the method comprising:

approximating the object using a figure for each of the frames;

extracting a plurality of points representing the figure for each of the frames;

approximating trajectories with functions, the trajectories being obtained by arranging, in the frames

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advancing direction, position data about the plurality of points in a reference frame and relative position data about the plurality of points in a succeeding frame with reference to the position data about the plurality of points in the reference frame; and

describing the object region data using the functions.

According to embodiments of the present invention, there is provided a further method of describing object region data about an object in video data over a plurality of frames, the method comprising:

approximating the object using a figure for each of the frames;

extracting a plurality of points representing the figure for each of the frames;

approximating trajectories with functions, the trajectories being obtained by arranging, in the frames advancing direction, data indicating positions of the plurality of points; and

describing the object region data using the functions and depth information of the object.

According to embodiments of the present invention, there is provided a still another method of describing object region data about an object in video data over a plurality of frames, the method comprising:

approximating the object using a figure for each of the frames;

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extracting a plurality of points representing the figure for each of the frames;

approximating trajectories with functions, the trajectories being obtained by arranging, in the frames advancing direction, data indicating positions of the plurality of points; and

describing the object region data using the functions and display flag information indicating a range of frames in which the object or each of the points is visible or not.

According to embodiments of the present invention, there is provided a still further method of describing object region data about an object in video data over a plurality of frames, the method comprising:

approximating the object using a figure for each of the frames;

extracting a plurality of points representing the figure for each of the frames;

approximating trajectories with functions, the trajectories being obtained by arranging, in the frames advancing direction, data indicating positions of the plurality of points; and

describing the object region data using the functions and object passing range information indicating a range where the figure approximating the object exist over the plurality of frames.

According to embodiments of the present invention,

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there is provided a still further method of describing object region data about an object moving in a panorama image formed by combining a plurality of frames with being overlapped, the method comprising:

5 approximating the object in the panorama image using a figure;

 extracting a plurality of points representing the figure in a coordinate system of the panorama image;

 approximating trajectories with functions, the
10 trajectories being obtained by arranging, in the frames advancing direction, data indicating positions of the plurality of points; and

 describing the object region data using the functions.

15 BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

 The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention, and together with the general description
20 given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

 FIG. 1 shows an object region data creating apparatus according to a first embodiment of the
25 present invention;

 FIG. 2 is a flowchart for processing in the object region data creating apparatus according to the first

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embodiment;

FIGS. 3A, 3B, and 3C are diagrams to help schematically explain the process of describing the object region in an image using object region data;

5 FIG. 4 is a diagram to help explain an example of finding a function that approximates the value of the X-coordinate of a reference representative point;

10 FIG. 5 is a diagram to help explain differential vectors for depicting representative points other than the reference representative point;

15 FIG. 6 is a diagram to help explain an example of finding a function that approximates the values of the X components of the differential vectors for depicting representative points other than the reference representative point;

FIG. 7 is a flowchart for the process of finding an approximate function from the coordinates of representative points or differential vectors;

20 FIG. 8 shows an example of the structure of object region data;

FIG. 9 shows an example of the structure of the representative point trajectory data in the object region data;

25 FIG. 10 is a diagram to help explain another example of differential vectors for depicting representative points other than the reference representative point;

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FIGS. 11A and 11B are diagrams to help explain still other examples of differential vectors for depicting representative points other than the reference representative point;

5 FIG. 12 is a diagram to help explain an example of differential vectors between frames;

FIG. 13 shows another example of the structure of the object region data;

10 FIG. 14 is a flowchart for the process of extracting the object region at a give time from the object region data;

FIG. 15 shows an object region data creating apparatus according to a second embodiment of the present invention;

15 FIG. 16 shows an example of the structure of the representative point trajectory data in the object region data according to a second embodiment;

FIG. 17 shows still another example of the structure of the object region data;

20 FIG. 18 shows an example of the data structure of depth information;

FIG. 19 is an illustration to help explain the measurement of positional information in the direction of depth;

25 FIG. 20 is a flowchart for the process of searching for an object near the specified position;

FIGS. 21A and 21B are illustrations to help

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explain the measurement of positional information in the direction of depth;

FIG. 22 is a diagram to help explain the measurement of positional information in the direction of depth;

FIG. 23 is a diagram to help explain the measurement of positional information in the direction of depth;

FIG. 24 is a flowchart for the preprocess of determining the time when the moving body exists at the specified distance;

FIG. 25 is a flowchart for the process of determining the time when the moving body exists at the specified distance;

FIGS. 26A, 26B, and 26C are illustrations to help explain display flags according to a third embodiment;

FIG. 27 is a diagram to help explain the creation of representative point trajectory data;

FIG. 28 shows still another example of the structure of the object region data;

FIG. 29 shows an example of the structure of the display flag information;

FIG. 30 shows still another example of the structure of the representative point trajectory data in the object region data;

FIG. 31 is a flowchart for the process of searching;

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FIGS. 32A, 32B, and 32C are diagrams to help explain information about the object passing range according to a fourth embodiment;

5 FIG. 33 shows an example of the structure of the information about the object passing range;

FIG. 34 shows a still another example of the structure of the information about the object passing range;

10 FIG. 35 is a flowchart for the process of selecting an object passing the specified coordinate;

FIG. 36 is a flowchart for the procedure for processing by an object region data describing method using mosaicking techniques according to a fifth embodiment;

15 FIGS. 37A and 37B are diagrams to help explain the object region data describing method using mosaicking techniques;

FIG. 38 shows an example of the structure of the information relating to a coordinate conversion;

20 FIGS. 39A, 39B, 39C, and 39D are diagrams showing a procedure for describing an object region in a video with object region data according to a fourth embodiment;

25 FIG. 40 is a diagram showing an example of a process for approximating an object region with an ellipse;

FIG. 41 is a diagram showing an example of

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FIG. 43 is a diagram showing an example of the structure of data of an approximate figure in object region data;

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FIG. 47 is a diagram showing an example in which the object region in a video is expressed with a plurality of ellipses;

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FIG. 50 is a flowchart showing an example of a procedure for obtaining an approximate rectangle;

FIG. 52 is a flowchart showing an example of
5 a procedure for obtaining an approximate ellipse from
an approximate rectangle;

FIG. 54 is a diagram showing the second half of
10 the other example of the structure of object region
data;

FIG. 56 is a diagram showing a still further
15 example of the structure of object region data;

FIG. 58 is a flow chart showing one example of
20 processing procedure in the seventh embodiment;

FIG. 60 is an explanatory view for another example of the method of calculating an object region optical flow;

FIG. 61 is an explanatory view for an example of expressing a conversion parameter by an approximate

temporal function;

FIG. 62 shows one example of an object region data description format if the reference object region is expressed by a bit map;

5 FIG. 63 shows an example of the constitution of the object region data creating apparatus in the seventh embodiment;

FIG. 64 is a flow chart showing another example of processing procedure in the seventh embodiment;

10 FIG. 65 is an explanatory view for a method of making the representative points of an approximate figures of object regions correspond to each other;

15 FIG. 66 shows the relationship between the types of approximate figures and conversion models for which conversion parameters can be obtained;

FIG. 67 shows one example of a description format for the object region data if the reference object region is approximated by a figure;

20 FIG. 68 shows one example of the description format of object region data including sampling information;

FIG. 69 is an explanatory view for a state in which one object is divided into regions having similar movement by an optical flow; and

25 FIG. 70 shows one example of an object region data description format for describing one object in a plurality of regions.

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DETAILED DESCRIPTION OF THE INVENTION

A preferred embodiment of an object region data describing method and an object region data creating apparatus according to the present invention will now be described with reference to the accompanying drawings.

First Embodiment

FIG. 1 shows the configuration of an object region data creating apparatus (or an object region data converting system) according to the first embodiment of the present invention.

As shown in FIG. 1, the object region data creating apparatus comprises a video data storage device 100, a region extracting device 101, a region figure approximating device 102, a figure representative point extracting device 103, a representative point trajectory function approximating device 104, and an object region data storage device 106. It may further comprise a related information storage device 105.

FIG. 2 is a flowchart for processing in the object region data creating apparatus.

The video data storage device 100, which stores video data, is composed of, for example, a hard disk, an optical disk, or a semiconductor memory.

The region extracting device 101 extracts a partial region of the video data (step S1).

The partial region is generally the object region, such as a specific person, plant, animal, car, or building, in the image. Any thing in the video may be used as the object region, as long as it can be treated as an object in the video. The object may be an independent thing, part of a thing (e.g., the head of a person, the hood of a car, or the entrance of a building), a set of things (e.g., a flock of birds or a school of fish). In images, the same object frequently appears on consecutive frames, whereas the region corresponding to the same object often varies from frame to frame mainly because of the movement of the object itself and/or the movement of the camera during shooting.

The region extracting device 101 is for extracting the object region in each frame according to the movement or transformation of the target object. As a concrete extracting method, any one of the following methods can be used: a method of manually specifying the region all over the frames, a method of extracting the contour of an object consecutively using a dynamic contour model called Snakes as described in M. Kass, et al., "Snakes: Active contour models," International Journal of Computer Vision, Vol. 1, No. 4, July, 1988, pp. 321-331, a method of estimating the transformation and movement of the whole of an object from the destination of the movement of the partial region of the object determined by block matching as described in

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Kaneko, et al., "A fast moving body tracking method for creating hypermedia content using robust estimation," Technical Report by Information Processing Society, CVIM 113-1, 1998, and a method of determining the regions having similar colors by the growth and division of the region as described in "Image Analysis Handbook," Sect. 2, Chapter 2, Tokyo University Publishing House, 1991.

The region figure approximating device 102, using a specific figure, approximates the object region extracted by the region extracting device 101 (step S2).

Various types of figure, including a rectangle, a circle, an ellipse, and a polygon, can be used. The type of figure used in approximation may be determined in advance. For example, the type of figure may be specified by the user, using specific units, such as each of the objects to be approximated. Alternatively, the type of figure may be selected automatically according to the shape or the like of each of the objects to be approximated.

There are various method of approximating the region. They include a method of approximating the region using a circumscribed rectangle of the object region, a method of approximating the region using a circumscribed ellipse or inscribed ellipse for the rectangle found by the preceding method, a method of

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approximating the region using a circumscribed ellipse for the object region, a method of creating an initial approximate polygon for the object region and then decreasing the number of vertexes of the approximate polygon so that the difference in area between the object region and the approximate polygon may lie within a reference, and a method of approximating the region using a polygon with a predetermined number of vortexes. Still another method is to approximate the region better using inclined figures. There are further methods taking other geometric amounts into account. They include a method of causing the center of gravity of the object region to coincide with the center of gravity of the approximate figure and a method of setting the area of the approximate figure to the value obtained by multiplying the area of the object region by a specific constant.

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The region figure approximating device 102 approximates the region frame by frame each time it receives the result of the extraction at the region extracting device 101. Alternatively, the figure may be approximated using the result of extracting the regions in several frames before and after the present frame. When the result of extracting the regions in several frames is used, changes in the size and position of the approximate figure are smoothed between several frames, which make it possible to smooth the

5 The figure representative point extracting device
103 extracts representative points depicting the
approximate figure outputted from the figure approxi-
mating device 102 (step S3). What points are set as
representative points depends on what approximate
10 figure is used. For example, when the approximate
figure is a rectangle, four or three vertexes can be
set as representative points. When the approximate
figure is a circle, the center and one point on the
circumference or the both ends of the diameter can be
15 set as representative points. When the approximate
figure is an ellipse, the vertexes of a circumscribed
rectangle for the ellipse may be set as representative
points (in this case, too, three of the four vertexes
are sufficient) or two foci of the ellipse and one
20 point on the ellipse (e.g., one point on the minor
axis) may be set as representative points. When any
closed polygon is used as the approximate figure, each
vertex has only to be set as a representative point.

Representative points are extracted in each frame
each time the figure approximating device 102 outputs
information about the approximate figure for one frame.
Each representative point is represented by the

The representative point trajectory function approximating device 104 approximates a time series of the positions of the representative points extracted at the figure representative point extracting device 103 (or the amounts that enable the points to be determined) and arranged in the frames advancing direction, using a function (or approximate function) of time t (e.g., a time stamp assigned to an image) or frame number f (step S4). This function is expressed for each representative point and differs in expression, depending on whether X-coordinate or Y-coordinate are used.

A straight line or a spline curve may be used as a function representing a representative point trajectory.

The determined approximate curve (including

a straight line) is recorded as object region data according to a specific format in the object region data storage device 106.

5 The related information storage device 105, which is provided if necessary, is for storing information (related information) about the objects appearing in the video data stored in the video data storage device 100 and pointer information (including addresses in which related information has been recorded, file names, and URLs) used to acquire the related information from an external storage device or a server via a network. The related information may be characters, sound, still pictures, moving pictures, or a suitable combination of them. Furthermore, the related information may be programs or data that describes the operation of the computer (in this case, when the object is specified by the user, the computer carries out a desired operation). The related information storage device 105 is composed of, for example, a hard disk, an optical disk, or a semiconductor memory, as is the video data storage device 100.

25 The object region data storage device 106 is a storage medium into which object region data including the data that represents a curve equation approximating a time-sequential trajectory of the positions (the quantity that enables the positions to be determined) of the representative points outputted from the

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representative point trajectory function approximating device 104. With the configuration including the related information storage device 105, when the related information about the object corresponding to the region expressed by the function is stored in the related information storage device 105, the related information itself and the addresses in which the related information has been recorded can also be recorded in the object region data (when information about the addresses in which the related information has been recorded is stored in the related information storage device 105, the address information can also be recorded). The object region data storage device 106 is composed of, for example, a hard disk, an optical disk, or a semiconductor memory, as is the video data storage device 100.

The video data storage device 100, related information storage device 105, and object region data storage device 106 may be composed of separate storage devices. Alternatively, all of them or part of them may be composed of the same storage device.

Such an object region data creating apparatus may also be realized by executing software on the computer.

In the processing on the object region data creating apparatus (particularly, the processing at the region extracting device 101 or at the figure approximating device 102), when the user is allowed to

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operate the system, a GUI is used to display the video data in, for example, frames and enable the user to input instructions (which part is omitted in FIG. 1).

Using a more concrete example, the operation of the object region data creating apparatus will be explained.

Explanation will be given showing an example of approximating the object region with a polygon (with the vertexes of an approximate polygon as representative points) and using a second order polynomial spline function as an approximate function. In an example of using a polygon as an approximate figure in the following explanation, the vertexes of a polygon generally means representative points.

FIGS. 3A to 3C are diagrams to help give an outline of a series of processes ranging from the process of extracting the object region with the region extracting device 101, the process of approximating the region using figures with the figure approximating device 102, the process of extracting the representative points of the figure with the figure representative point extracting device 103, to the process of approximating the representative point trajectory using a function by means of the representative point trajectory function approximating device 104.

In FIG. 3A, numeral 200 indicates one frame in

an image to be processed.

Numeral 201 indicates the object region to be extracted. The process of extracting the region 201 of the object is carried at the region extracting device 101.

Numeral 202 indicates an approximate polygon obtained by approximating the object region using a polygon. The process of finding the approximate polygon 202 from the object region 201 is carried out at the figure approximating device 102.

FIG. 3B illustrates representative points of the approximate figure over a plurality of frames, or the change of the vertexes of the approximate polygon 202 in the example and an approximate curve of those vertexes.

In the first embodiment, a specific representative point selected from a plurality of representative points on the approximate figure is called a reference representative point, which is denoted by V_0 (the reference representative point is supposed to be the same all over the frames). In the embodiment, let any one of a plurality of vertexes of the approximate polygon 202 be the reference representative point V_0 .

There are various selecting methods. They include a method of selecting the point having the largest or smallest X-coordinate or Y-coordinate and a method of selecting the top right point, bottom right point,

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bottom left point, or top left point.

In the second and later frames, the reference representative point V_0 is selected by judging which one of a plurality of representative points in the present frame corresponds to the reference representative point V_0 corresponding to the preceding frame.

There are various methods of judging which representative point corresponds to the reference representative point V_0 in the preceding frame.

For example, they include a method of setting, as the reference representative point V_0 , the point in the present frame closest to the reference representative point V_0 in the preceding frame, a method of setting, as the reference representative point V_0 , the point in the present frame closest to the reference representative point V_0 in the preceding frame when the center of gravity of the approximate figure in the preceding frame is caused to coincide with the center of gravity of the approximate figure in the present frame, a method of finding the reference representative point V_0 in the present frame by checking a plurality of representative points of the approximate figure in the preceding figure against a plurality of representative points of the approximate figure in the present figure, and a method of finding the reference representative point V_0 in the present frame by checking the video data in the region of the target object in the

preceding frame against the video data in the present frame.

Methods of causing representative points other than the reference representative point V_0 to correspond to those in adjacent frames include methods similar to those described above and a method of causing other representative points to correspond to those in the adjacent frames, using the reference representative point as the starting point.

These processes are carried out at the representative point extracting device 103.

The representative point trajectory function approximating device 104 finds an approximate function expressing the trajectory 203 from the coordinates of the reference representative point V_0 in each frame inputted one after another. In FIG. 3B, numeral 203 indicates the trajectory obtained by connecting moving locations of the reference representative point V_0 in individual frames.

The coordinates of the reference representative point V_0 include the X-coordinate and Y-coordinate. Each of the coordinates is approximated independently by a function of time t or frame number f .

Numeral 204 in FIG. 3C indicates an example of the function found for the reference representative point V_0 (in this case, only X-coordinate axis for the reference representative point V_0 is shown).

FIG. 4 shows an example of finding a function for approximating the value of the X-coordinate of the reference representative point V_0 . In FIG. 4, numeral 301 indicates the time section where the object exists. The black point 302 represents the value of the X-coordinate of the reference representative point V_0 . Numeral 303 indicates its approximate function. As for the Y-coordinate, an approximate function is found in the same manner. Since polynomial spline functions are used as approximate functions, a polynomial is defined for each of the time sections divided at points called knots. In this case, each of $t = 0$, $t = 5$, and $t = 16$ makes a knot time.

20 Representative points other than the reference
representative point V_0 may be represented using the
relative relationship with other representative points,
or using differential vectors. They are described by
the trajectory of the vectors.

Hereinafter, explanation will be given showing an example of describing representative points other than the reference representative point V_0 using the

trajectory of a vector from an adjacent representative point.

FIG. 5 is a diagram to help explain one vertex, the reference representative point V_0 , and individual differential vectors representing the other vertexes.

The individual vertexes other than the reference representative point V_0 are denoted by V_1, V_2, \dots, V_{M-1} , starting from the reference representative point V_0 in a predetermined order, for example, clockwise. Here, M is the number of vertexes. Since the figure in FIG. 5 is a pentagon, this gives $M = 5$. The vector from vertex V_0 to V_1 is denoted by $V_{0,1}$. Vector $V_{1,2}, V_{2,3}, \dots, V_{M-2,M-1}$ are determined in the same manner. Each vector has the values (relative position data) of the X component and Y component viewed from the starting point of the vector.

A string of black points 502 in FIG. 6 represents the value of the X-component of vector $V_{0,1}$ at each time.

The process of finding these vectors is carried out at the representative point extracting device 103.

The representative point trajectory function approximating device 104 calculates an approximate function 503 that expresses the values of the X-component and Y-component of each vector.

When the shape of the object hardly changes and the movement of the object is close to parallel

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translation, the values of vectors $V_{0,1}$, $V_{1,2}$, ..., $V_{M-2,M-1}$ do not change much. As a result, the difference between the approximate function and the actual values becomes smaller, which makes it possible to expect an improvement in the efficiency in describing the object region. If the shape of the object does not change and the movement of the object is completely parallel translation, the values of vectors $V_{0,1}$, $V_{1,2}$, ..., $V_{M-2,M-1}$ do not change at all, with the result that all the approximate function makes a straight line and approximation errors are zero.

FIG. 7 is a flowchart for an example of the process of finding an approximate function for the coordinates of the representative points or the component values of the differential vectors from the coordinates of the representative points (in this example, the vertexes of the approximate polygon for the object region) inputted one after another to the representative point trajectory function approximating device 104 or from the component values of the differential vectors.

Here, let the time corresponding to the I -th frame be t_i ($i = 0, 1, \dots$). Moreover, let $v^{(0)}_t$ be the X -coordinate of V_0 at time t and let $v^{(j)}_t$ ($j = 1, 2, \dots, M-1$) be the X -component value of $V_{j-1,j}$ at time t . In addition, let the largest of the times t corresponding to the knots of the determined spline function

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be t_k .

First, at step S601, the initial setting of t_k and i is done.

At step S602, an approximate function of $v(j)_t$
5 (in the first embodiment, a quadratic polynomial) is
found over the section ranging from t_k to t_i , each
corresponding to a knot. A method of finding an
approximate function by least squares is most widely
used. In this case, however, a condition that the
10 approximate function passes knots must be added. The
reason is that, without this condition, a polynomial
spline function becomes discontinuous at knots.
In FIG. 7, the approximate function $v(j)_t$ found over
the section ranging from t_a to t_b is denoted by
15 $F(j)_{t_a, t_b}(t)$ ($j = 0, 1, \dots, M-1$), the starting point
 $v(j)_k$ is denoted by $F(j)_{t_k, t_i}(t_k)$, and the ending
point $v(j)_i$ is denoted by $F(j)_{t_k, t_i}(t_i)$.

Next, at step S603, an approximation error $e(j)$
($j = 0, 1, \dots, M-1$) of the approximate function is
20 calculated. The approximation error is calculated
using the following equation:

$$e(j) = \max |v(j)_{t_h} - F(j)_{t_k, t_i}(t_h)|$$

where the range of h taken into account is $k \leq h$
 $\leq i$.

25 At step S604, it is determined whether or not
the approximation error is within a permitted limit.
The range of the allowed errors may be set to the same

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value for all the vertexes. Alternatively, each vertex may be permitted in a different range. If any one exceeds the allowed error range, control proceeds to step S605. If all the vertexes are within the allowed error range, control goes to step S606.

At step S605, the approximate function for the section ranging from t_k to t_{i-1} is determined to be $F^{(j)}_{t_k, t_{i-1}}(t)$ ($j = 0, 1, \dots, M-1$) and the parameter "k" is set to "i-1".

At step S606, the value of i is incremented by one. Thus, the same approximate function is applied for a section in which the error is within an allowable limit and a new approximate function is found if the error is not within the allowable limit.

At step S607, if the coordinate (or the component value of its difference vector) of a new representative point is not be inputted in an end judging process, the process is completed. If the coordinate (or the component value) of a representative point is inputted, the processes at step S602 and forward are carried out again.

If the end determination is affirmative, at step S608, the approximate function for the section ranging from t_k to t_{i-1} is determined to be $F^{(j)}_{t_k, t_{i-1}}(t)$ ($j = 0, 1, \dots, M-1$).

Although only the X-coordinate has been explained in FIG. 7, the same holds true for the Y-coordinate.

In judging errors, errors may be evaluated simultaneously for all the X-coordinates and Y-coordinates of the individual vertexes.

5 The process at the representative point trajectory
function approximating device 104 may be carried out
each time the coordinates (component values) of the
representative points of each frame for the object
region are obtained (for example, approximation is made
each time the coordinates (component values) of the
10 representative points for each frame are obtained and
simultaneously an approximation error is determined.
Knots are provided in such a manner that the approxima-
tion error lies in a specific range, thereby dividing
the approximation section suitably) or after the
15 coordinates (component values) of the representative
points of all the frames for the object region have
been obtained.

20 When the representative point trajectory data for
the object region is created, the knots may be made
the same for the coordinates of all the representative
points. For example, when the coordinates (or
component values) of the representative points
are approximated, if a knot whose error exceeds
an allowable value is provided in approximating
25 a representative point, the same knot is forcibly
provided for all the other representative points in
the approximating process.

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The approximate function thus obtained, such as a spline function, is recorded in the object region data storage device 106 according to a predetermined data format.

5 Hereinafter, the format of the object region data stored in the object region data storage device 106 will be explained. Explanation will be given using a case where representative points are approximated by a spline function. Representative points may be
10 approximated by another suitable function.

FIG. 8 shows an example of the format of the object region data.

Figure type ID 700 determines the type of the figure used in approximating the object region.
15 For instance, the center of gravity (centroid), rectangle, ellipse, or polygon can be specified.

Number of representative points 703 indicates the number of representative points determined by the figure type.

20 Representative point trajectory 704 describes the trajectory of a representative point. There are as many trajectory as equal the number of representative points M. When representative points other than the reference representative point V_0 are described by the
25 trajectory from an adjacent representative point, the trajectory of the reference representative point V_0 is described in the first representative point trajectory

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(1) 704; the trajectory of $V_{0,1}$ is described in the second representative point trajectory (2) 704; the trajectory of $V_{1,2}$ is described in the third representative point trajectory (3) 704; and the trajectory of $V_{M-2,M-1}$ is described in the M-th representative point trajectory (M) 704.

When approximate functions are found for representative points other than the reference representative point V_0 in the same manner as the reference representative point, the trajectory of V_0 is described in the first representative point trajectory (1) 704; the trajectory of V_1 is described in the second representative point trajectory (2) 704; the trajectory of V_2 is described in the third representative point trajectory (3) 704; and the trajectory of V_{M-1} is described in the M-th representative point trajectory (M) 704.

Object appearing time 701 is the time when the desired object appeared. Object existing time period 702 is the length of time during which the object existed. Object disappearing time may be substituted for object existing time period 702. Both object appearing time and object existing time period may be described by frame number and the number of frames instead of time. Since information about object appearing time 701 and object existing time period 702 can also be obtained from the knot time in

representative point trajectory 704, they need not necessarily be described.

5 The object appearing time/object appearing frame, object existing time period/object exiting frame, and object disappearing time/object disappearing frame may be determined by the frames in which the object actually appeared or disappeared in the image.

10 Alternatively, for example, any frame number after the appearance of the object in the image may be set as the start frame number and any frame number after the start frame number and before the one in which the object disappeared in the image may be set as the end frame number.

15 The object region data item may include an ID number, which is identification number assigned to each object.

20 A single object may be approximated by a plurality of approximate figures. In this case, the object region data includes, for example, as many figure type IDs, representative points, and representative point trajectories as equal the number of figures used in approximation.

FIG. 9 is a concrete example of the data format of the representative point trajectory.

25 Number of knots 800 indicates the number of knots of a spline function that expresses a representative point trajectory. The frame corresponding to each knot

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polynomial is used, 1 is set; and when a quadratic polynomial is used, 2 is set (of course, the highest degree of a polynomial may be set to degree 3 or higher). Since information about only knots is
5 sufficient in using a linear polynomial, function parameters are not described. When a quadratic polynomial is used, a single value for determining a coefficient (for example, a quadratic coefficient or the coordinate of one point other than the knots on the
10 quadratic curve (the component value when differential vectors are used)) is described in a function parameter. There are as many pieces of function specifying information as equal the number of knots minus one. They are described in arrangement form
15 811, 815.

In the methods explained above, to describe representative points other than the reference representative point V_0 , the differential vectors from adjacent representative points are found and converted
20 into approximate functions. In addition to this method, there is a method of using differential vectors from the reference representative point V_0 .

For example, as explained in FIG. 10, vector $V_{0,i}$ from V_0 to V_i is calculated for a representative point
25 V_i (in this case, each vertex of the approximate polygon) other than the reference representative point V_0 . Then, in the process of FIG. 7, $v(j)_t$ ($j = 1, 2,$

..., $M - 1$) is replaced with the component value of $V_{0,i}$ at time t .

This method has the advantage that, since any representative point other than the reference
5 representative point V_0 can be described by the reference representative point V_0 and a single vector, errors in the values obtained from the descriptive data are not accumulated.

There is another method of finding half of the
10 vectors clockwise, starting from the reference representative point V_0 , and the remaining half of the vectors counterclockwise as shown in FIG. 11A. Still another method is to provide a plurality of
15 representative points expressed by vectors from the reference representative point V_0 and then find vectors between adjacent vectors, as shown in FIG. 11B.

When the number of representative points of an approximate figure is a ($a \geq 3$), each of the
20 representative points equal to 2 or more and $(a - 1)$ or less may be set as the reference representative points and the remaining one or more representative points be expressed by differential vectors from the representative points.

In these cases, there are as many representative
25 point trajectory 704 of the object region data in FIG. 8 as equal the number of representative points M .

The method of expressing representative points

other than the reference representative point in various ways using the reference representative point in individual frames as the basic point has been explained. Hereinafter, a method of describing the object region by expressing the movement of a representative point by vectors in consecutive frames and converting the trajectory of these vectors into an approximate function will be explained.

In FIG. 12, numeral 1100 indicates an object approximate figure (polygon) in the initial frame. Numeral 1102 indicates an object approximate figure in the frame at time t . Numeral 1101 indicates an object approximate figure just before 1102. Numeral 1103 indicates one of the representative points of the object region at time t . Numeral 1104 indicates the representative point corresponding to the representative point 1103 in the preceding frame. Numeral 1105 indicates a motion vector from the representative point 1104 to the representative point 1103, representing the movement of a representative point in the frame at time t . Since the motion vector is obtained at each time corresponding to each frame, it is possible to perform approximation using a function of time t as described above.

A method of describing the object region is to execute the flowchart of FIG. 7 using $v(j)t$ ($j = 0, 1, \dots, M - 1$) as the component values of V'_i at time t .

Here, let the motion vector of V_i at time t be V'_i .
In this method, the motion vector of V_0 is calculated
in the same manner as those of the other representative
points and converted into an approximate function.

5 In a method using such a motion vector, the
coordinates of all the representative points of the
approximate figure in the frame where an object
appeared have to be described. Accordingly, the data
format (corresponding to the example of FIG. 8)
10 described in this method is as shown in FIG. 13.
The data format of FIG. 13 differs from that of FIG. 8.
in that representative point initial position 1200 is
added. In the representative point initial position
1200, the coordinates of M representative points in
15 the initial frame are described. In this case, the
coordinates of all the representative points have only
to be described directly. Another method is to
describe only the coordinate of one representative
point directly and further describe the coordinates of
20 the other representative points using differential
vectors from adjacent representative points as shown
in, for example, FIG. 5. Still another method is to
describe representative points using differential
vectors from one representative point V_0 as explained
25 in FIG. 10.

Still another method of describing the object
region data is to find directly the motion vector from

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the position of the initial representative point to the position of a representative point at time t and convert the motion vector into an approximate function.

5 Next, a method of extracting the object region at given time T from information about the object region described in the object region data will be explained. This process is executed at an information processing system that handles video data and its object region data. Such an information processing system can, of course, be realized by executing software on a computer.

FIG. 14 is a flowchart for an example of the process in that case.

15 The following is an explanation of describing representative points other than the reference representative point V_0 using the trajectory of a vector from an adjacent representative point.

20 At step S901, it is determined whether an object exists at a given time T . The determination can be made easily by referring to the object appearing time 701 and object existing time period 702. If no object exists at time T , this means that there is no object region. Thus, the process is ended immediately.

25 At step S902, the approximate function $F(j)_{t_a, t_b}(t)$ ($j = 1, 2, \dots, M-1$) at time T is restructured. Here, let the times at both end knots of time T be t_a and t_b . The approximate function can be

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reconstructed using the coordinates (or the component values of its difference vector) at t_a and t_b described at X-coordinate of knot 803 or Y-coordinate of knot 805, function ID 809, 813, and function parameter 810, 814, as shown in FIG. 9. That is, when a linear polynomial is used as the approximate function, it can be obtained as a straight line passing two knots. When a quadratic polynomial is used and a quadratic coefficient is described in the function parameter, the quadratic coefficient is determined from the value of the function parameter and the coefficient of lower than second order is determined in such a manner that the line passes knots.

At step S903, $t = T$ is substituted into the approximate function, thereby finding the coordinate of V_0 at time T and the component values of $V_{1,2}$, $V_{2,3}$, ..., $V_{M-2,M-1}$.

Finally, at step S904, V_0 and $V_{1,2}$, $V_{2,3}$, ..., $V_{M-2,M-1}$ are added one after another, thereby calculating the coordinates of V_0 , V_1 , ..., V_{M-1} .

On the basis of the representative points obtained in this way, the information processing system can carry out various processes. They include the process of creating a figure that approximates the object region, the process of showing the user the target object by depicting the region of the approximate figure in the object's video data in a specific

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can read a description of the desired actor by just clicking on the actor's image. Similarly, the related information can be applied to any type of electrical content, such as electronic encyclopedias or electronic catalogs.

For instance, in searching for an object, the passing position of the object, the non-passing position of the object, the size of the object at a certain position, and the stay time at a certain position can be used as search keys to search for an object that satisfies the condition. For any search key, whether the condition is satisfied can be judged by extracting the coordinates of representative points one after another in the time period during which the object exists, judging whether a given point is inside or outside the figure composed of representative points, and calculating the area.

Furthermore, describing a keyword in the related information enables the object to be searched for by the keyword. Moreover, describing the amount of feature, such as shape, texture, activity, or color, extracted from the object in the related information enables the object to be searched for on the basis of the amount of feature.

In addition, for example, on the basis of the quantity of feature, such as the shape, texture, activity, or color of the object obtained by analyzing

the object region data, a surveillance system for watching for a dubious character can be realized.

Hereinafter, a method of providing video data and object region data will be explained.

5 To provide the user with the object region data created by the processes of the first embodiment, the provider needs to offer the object region data to the user by any suitable method. Various modes of the providing method can be considered as described below:

10 (1) The mode of recording the video data, its object region data, and its related information onto a single recording medium (or plural recording mediums) and offering these data items to the user at the same time.

15 (2) The mode of recording the video data and its object region data onto a single recording medium (or plural recording mediums) and offering these data items to the user at the same time, but offering the related information separately to the user or not offering the
20 related information to the user (the latter case is that, for example, the user can acquire the related information via the Internet or the like, even if it is not offered to the user).

25 (3) The mode of offering the video data to the user independently, recording the object region data and related information onto a single recording medium (or plural recording mediums), and offering these data

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items to the user at the same time.

(4) The mode of offering the video data, object region data, and related data separately to the user.

5 In these modes, the data items are offered mainly with a recording medium. Alternatively, part or all of the data items may be offered with a communication medium.

10 As described above, in the first embodiment, the object region in the video can be described by the parameters of the curve that approximates the time-sequential trajectory of the representative points of the approximate figure (the trajectory of the coordinates (or the quantity that enables the values to be determined) of the representative points using the frame numbers or time stamps as variables). Therefore, 15 the amount of data used to determine the object region is decreased effectively and handling is made easier. When the object is a rigid body, the relative position varies less than the absolute position and a function 20 that approximates its trajectory can be described using a smaller amount of information. Moreover, the amount of communication in transmitting the data can be reduced. It is easy to create an approximate figure from the parameters of the approximate curve. When a 25 basic figure (e.g., a closed polygon) is used as a representative of the approximate figure, this makes it possible to determine whether or not any coordinate

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specified by the user is inside the object region
(approximate figure) (whether or not the object region
has been specified), using a simple determination
equation. Therefore, it becomes easy to specify the
5 moving object in the video so that it is easily search
the object based on the passing position of the object,
the non-passing position of the object, and the
stay time at a certain position. There is provided
a hypermedia application with easy handling.

10 Other embodiments of the object data creating
apparatus according to the present invention will be
described. The same portions as those of the first
embodiment will be indicated in the same reference
numerals and their detailed description will be
15 omitted.

Second Embodiment

A second embodiment of the present invention is
such that information on the direction of depth, in
addition to the two-dimensional information on the
20 screen, is included in the object region data about
an object in the image in the first embodiment.
Explanation will center on the difference between the
second embodiment and the first embodiment.

In the second embodiment, the object region data
25 creating apparatus of the first embodiment has to be
further provided with a processing device 108 for
obtaining information about the direction of depth

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(hereinafter, referred to as depth information). The depth information processing device 108 is connected between the video data storage device 100 and the representative point trajectory function approximating device 104, as shown in FIG. 15.

There are two methods of giving depth information: one method of giving depth information in consecutive values (Z-coordinates) and the other method of giving depth information in discrete level values (more preferably integral values in a specific range).

When the video data comes from a video camera, each value is based on the data obtained by measuring the object or is specified by the user. When the video data is artificial (as in CG or animation), the video data is based on the value about depth, if this value is given, or is specified by the user.

In each of the above cases, the depth information is given to each target object or to each representative point of an approximate figure of the target object.

In each combination of the above methods, the depth information is given to all of the frames ranging from the object appearing frame to object disappearing frame or to all of the specific sections (e.g., the adjacent knot sections) of the frames ranging from the object appearing frame to object disappearing frame.

When the method of using consecutive values as the

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depth information, the method of giving the depth information to each representative point, and the method of giving the depth information to all the frames ranging from the object appearing frame to object disappearing frame are used, the Z-coordinate of each representative point is subjected to the same process as are the X-coordinate and Y-coordinate of each representative point of the approximate figure of the target object in the first embodiment (this process is carried out at the representative point trajectory function approximating device 104).

In this case, an example of the data format of a representative point trajectory of the object region data (e.g., the object region data of FIG. 8 and its variations) is shown in FIG. 16. FIG. 16 differs from FIG. 9 in that an arrangement of Z-coordinates of knot 832 and an arrangement of function (Z) specifying information 836 are added to the X-coordinate and Y-coordinate.

When the method of using consecutive values as the depth information, the method of giving the depth information to each target object, and the method of giving the depth information to all the frames ranging from the object appearing frame to object disappearing frame are used, the Z-coordinate of the target object is subjected to the same process as are the X-coordinate and Y-coordinate of each representative

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processing device for obtaining the depth information measures the values.

The depth information includes such absolute information as the distance from the camera or a coordinate in a coordinate system set in a three-dimensional space and such relative positional information as the moving distance from the initial object position or the numerical value representing the magnitude of the moving distance.

Since it is generally difficult to find absolute positional information from the image taken by a single camera, the positional information is acquired by making measurements using a special range sensor as described in Iguchi and Sato, "Three-dimensional image measurement," Shokodo, pp. 20-52, or using a plurality of cameras and a stereo method. When a certain imaging condition can be assumed, however, the positional information can be obtained even from the image taken by a single camera. An example of this case will be given below.

For example, in watching a road, a car 1301 is imaged by a camera 1300 as shown in FIG. 19. Since the camera is generally fixed, the camera 1300 can be calibrated in advance. A plane equation can be calculated in a three-dimensional space in advance, provided that the road surface on which the car runs is a flat surface. Under these preconditions, the

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position of a point 1306 where the tire section of the car touches the ground 1303 is determined. On an image pickup plane 1302, the point 1306 is assumed to have been sensed at the position of a point 1305. On this assumption, the intersection of the viewing line 1304 of the camera passing the point 1305 and the plane 1303 is determined, thereby finding the position of the point 1306.

The viewing line 1304 of the camera can be calculated from the camera parameter obtained from calibration. Although the road surface is known, the height of the car's bumper may be assumed to be known.

For example, in the information processing system that handles the video data and its object region data, an object close to the specified position can be searched for using these three-dimensional data items.

FIG. 20 is a flowchart for such a searching process.

First, at step S2700, positional information about the specified object to be searched for is inputted.

At step S2701, the distance between its position and the object's three-dimensional position related to the whole object region data is calculated.

After the three-dimensional distance has been calculated for all the objects, the objects whose distance is smaller than a threshold value are found and outputted. Instead of determining the threshold

value, the object whose distance is the smallest may be outputted as the result of the searching.

It is difficult to determine the absolute positional information about the object in the video from only the general video. In the case of the image of a car coming closer from FIG. 21A to FIG. 21B taken by a stationary camera, observing changes in the size of the car on the image screen makes it possible to determine such relative depth information as tells whether the car was coming closer to or going farther away from the camera. An example of this case will be given below.

An ordinary camera optical system can be illustrated using a perspective transformation model based on a pinhole camera as shown in FIG. 22. Numeral 1600 is the lens principal point of a camera and 1601 an imaging plane. It is assumed that an object 1602 is moving closer to the camera. FIG. 23 is a view of the situation taken from above. As shown in FIG. 23, it is assumed that the object moves closer to the camera, while keeping parallel with the Z-axis. The width 1704 of the image of the front side of the object 1704 before movement increases to the width 1705 of the image of the front side of the object 1705 after movement. The smaller the distance between the object and the camera lens principal point 1700, the larger the image. Thus, changes in the relative position can

be expressed using the size of the image. For example, let the width of the image at the initial position of the object be 1. On this assumption, the ratio of the initial width to that of a subsequent image is calculated. Since the width of the image can be considered to be proportional to the reciprocal of the distance from the lens principal point 1700, the reciprocal of the value of the ratio is calculated and held as the depth information. In this case, the closer the car gets to the camera, the smaller the value. The farther the car goes away from the camera, the larger the value. Instead of width, the area of the image or the area of a characteristic texture of the object surface may be used.

For example, in the image processing system that handles video data and its object region data, use of information that tells changes in these relative positions makes it possible to find the time when one moving object will be at a specified distance.

FIGS. 23 and 24 are flowcharts for examples of the process in this case.

FIG. 24 is a flowchart for the preprocess of actually making a search. In FIG. 24, the depth value one moving object holds is normalized. At step S2800, let the smallest value of the depth value be 1. At step S2801, the depth value is normalized by dividing the smallest value. At step S2802, it is determined

that all the processes have been completed.

Next, at step S2900 in FIG. 25, the depth value is inputted. At step S2901, the difference between the input value and the depth value is calculated. After the input value has been compared with all the depth values (step S2902), the time at which the difference is the smallest is outputted (step S2903).

With the second embodiment, adding information on depth as well as the two-dimensional positional information, plane information, makes it possible to search for an object, taking into account the direction of depth, for example, the distance information from the camera.

Third Embodiment

A third embodiment of the present invention is such that display flag information is further included in the object region data in the video in the first or second embodiment. The display flag information is related to a display flag that indicates whether an object (or part of the object) is visible or invisible because it hides behind another object. Explanation will center on the difference between the third embodiment and the first or second embodiment.

In the third embodiment, a process related to the display flag is carried out at, for example, the representative point trajectory function approximating device 104.

5 To describe this state, display flag information is
added to the object region data.

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the corresponding part of the object is displayed).

A display flag is given to each interval between key points. It is determined at the same time that representative point trajectory data about the object region is created. Key points may be provided independently of the knots of an approximate function or in such a manner that they never fail to fall on the knots. For instance, when a key point occurs, that point of time may be forcibly made a knot.

When a display flag is given to each target object, a key point is set when the object changes from the visible state to the invisible state or vice versa. In an example in FIG. 27, an object 2201 is visible until frame i and disappears from frame i to frame j. From frame j and forward, when the object appears again, a key point is placed at frame i and frame j. Then, the disappearing state is set to the display flags for frame i to frame j and the disappearing state is set to the display flags for the remaining frames. The same holds true when a display flag is given to each representative point of an approximate figure for the target object.

The representative point trajectory data is created on the assumption that the object is visible over all the frames. When information about the representative points is unknown because the object hides behind another object, the representative point

trajectory data is created by supplementing the data with information about the representative points before and after the unknown representative points. After the representative point trajectory data has been created,
5 a flag is set, depending on whether the object is visible or invisible. Therefore, even when an object appears and disappears, it can be expressed by a series of representative point trajectory data items.

Hereinafter, variations of the display flag
10 information will be described.

Although a display flag is normally set to each interval between key points, a start time stamp and an end time stamp may be added to a display flag itself. This has the merit of being able to set a visible range
15 and an invisible range independently of key points.

A display flag may be given to each object. Alternatively, it may be given independently to each representative point trajectory data item. For instance, when an object is represented by a polygon
20 and its individual vertexes are expressed as representative points using trajectory data, giving a display flag to each representative point trajectory data item enables only an invisible part of the object to be represented.

25 In addition to showing whether the object is visible or invisible, the display flag may take the value of an integer representing priority. When

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FIG. 29 shows an example of the structure of display flag information 705.

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when the start time stamp 2302 and end time stamp 2303
are not used in the total number of display flags,
the number of display flags P 2301 may be omitted.
Display flag 2304 takes the value of 0 or 1 to indicate
5 appearance or disappearance. It may take an integer
value to represent priority.

When a display flag is given to each representa-
tive point of an approximate figure for the object,
display flag information is added to, for example, each
10 representative point trajectory of the object region
data (for example, that in FIG. 8 or its variations).

FIG. 30 is an example of the structure of the
representative point trajectory data in that case.
An example of the structure of display flag 900 in
15 FIG. 30 is as described above.

FIG. 31 is a flowchart for an example of the
searching process at the information processing system
that handles video data and its object region data.

First, at step S251, the user enters a search key.
20 At step S253, the distance between the key information
for the object region being searched for and the search
key is calculated.

At step S254, it is determined whether or not
the display flag for the object region corresponding to
25 the search key is visible. If the display flag is
invisible, matching is considered to be unsuccessful.

At step S255, when a display flag is visible and

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5 This is carried out for all the objects. When it is determined at step S252 that calculations have been done for all the object regions, then the result of the calculations is outputted at step S256, which completes the process.

15 Fourth Embodiment

25 In the fourth embodiment, there is further
provided a processing device for creating object
passing range information which is connected between

the region extracting device 101 and the region figure approximating device 102.

When an object is represented by the representative point trajectory data about the object region, one object is normally represented using a plurality of trajectory data items. In searching for an object that passed the specified point, it would be convenient for the object passing range to be represented without calculating the object region from a plurality of trajectory data items.

To achieve this, object passing range information about such a minimum rectangle or polygon as encloses the whole trajectory of the object is created. This information is added to the object region data.

When a rectangle is used, it may have or have not an inclination. Use of a rectangle with an inclination has the advantage that the trajectory of the object region can be approximated with smaller errors. Use of a rectangle with no inclination has the advantage that it is easy to calculate parameters for the rectangle.

In FIG. 32A, numeral 2402 shows an example of approximating the trajectory region of an object 2401 using a rectangle with no inclination.

In FIG. 32B, numeral 2403 shows an example of approximating the trajectory region of the object 2401 using a rectangle with an inclination.

In FIG. 32C, numeral 2404 shows an example of

approximating the trajectory region of an object 2401 using a polygon.

To calculate such a minimum rectangle or polygon as encloses the whole trajectory of the object, the region is found in each frame, then the logical sum of the regions over all the frames is calculated, and thereafter the resulting logical sum region is approximated by the smallest rectangle or polygon.

In calculating such a minimum rectangle or polygon as encloses the whole trajectory of the object, the logical sum of the smallest rectangle or polygon that encloses the whole trajectory of the object region related to the already calculated frames and the object region in a newly added frame may be calculated and the resulting logical sum region may be approximated by the smallest rectangle or polygon.

Furthermore, when such a minimum rectangle or polygon as encloses the whole trajectory of the object is calculated, such a minimum rectangle or polygon as encloses the trajectory of each representative point may be calculated and then such a minimum rectangle or polygon as encloses the logical sum of the regions of the rectangles or polygons obtained over all the trajectory be calculated.

FIG. 33 shows object passing range information added to the object region data. Circumscribing figure type 3401 indicates the rectangle with no inclination

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as shown in FIG. 32A if it is 0, the rectangle with an inclination as shown in FIG. 32B if it is 1, and the polygon as shown in FIG. 32C if it is 2. Number of apexes N 3402 is 2 if the circumscribing figure type 3401 is 0, 3 if the circumscribing figure type 3401 is 1, and arbitral number if the circumscribing figure type 3401 is 2. If the object has depth information, a three dimensional circumscribing figure is introduced and the object passing range information is added with the depth information as shown in FIG. 34.

FIG. 35 is a flowchart for an example of the process of, when the user specifies an coordinate, selecting such an object as passes the coordinate at the information processing system that handles, for example, video data and its object region data.

At step S261, the user enters a coordinate to be searched for. At step S262, such a minimum rectangle or polygon as encloses the whole of each object trajectory is compared with the inputted coordinate and only objects included in the smallest rectangle or polygon which encloses the whole trajectory are extracted (the number of extracted objects may be 0, 1, or more). At step S263, it is determined for the extracted objects whether or not the coordinates inputted from the representative point trajectory are in the object region (for example, inside the approximate figure).

Generally, judging the inside or outside of the smallest rectangle or polygon that encloses the whole trajectory requires a smaller amount of calculations than judging the inside or outside of the object based on the representative point trajectory. When the number of objects to be searched for is large, first judging the inside or outside of the smallest rectangle or polygon that encloses the whole trajectory enables an efficient search.

As described above, adding information about the smallest rectangle or polygon that encloses the whole trajectory of the object enables the passing range of the object to be represented efficiently. This makes it easier to determine whether an object passes a certain point.

To increase search efficiency, not only expressing the object region in a function but also giving a figure enclosing the position in which an object exists temporally and spatially makes it possible to eliminate objects located in completely different places from the things to be searched for.

Fifth embodiment

The fifth embodiment of the present invention is such that the invention is applied to mosaicking.

Mosaicking is a method of combining pictures taken in such a manner that they are partially overlapped with each other to form a single wide-range picture.

Such a combined picture is called a panorama picture. A plurality of methods of forming a panorama picture from a plurality of pictures have been proposed (as described in, for example, M. Irani and P. Anandan, "Video Indexing Based on Mosaic Representations," Proceedings of the IEEE, Vol. 86, No. 5, May 1998, pp. 905-921.).

The configuration of the fifth embodiment is basically the same as that of each of the first to fourth embodiments. The fifth embodiment differs from the first to fourth embodiments in that the representative points of an approximate figure is represented by a coordinate system of the whole panorama picture not by coordinate systems of the respective pictures.

Hereinafter, explanation will center on the difference between the fifth embodiment and the first to fourth embodiments.

FIG. 36 is a flowchart for an example of processing by an object region data describing method using mosaicking techniques. FIGS. 37A and 37B are diagrams to help explain the method.

A panorama picture itself is a single picture. The coordinates of each pixel of the individual still pictures before combination are converted using a certain reference point (for example, the left bottom point in a frame) in a panorama image as the origin.

Therefore, the individual representative points of an approximate figure for the object region in each still picture become a series of X-coordinates or a series of Y-coordinates in a coordinate system for the panorama image. In the fifth embodiment, a series of X-coordinates or Y-coordinates of the individual representative points of an approximate figure for the object region in each still picture is approximated using a function as in the first to fourth embodiments. For example, a difference vector is obtained in a single still picture or between still pictures. A series of the coordinates of the vector is approximated using a function.

At step S1900, a panorama picture is formed from a plurality of still pictures inputted. These input images are shown as 2000 to 2005 in FIG. 35A. They were obtained by photographing a moving body, while moving a camera. Numeral 2006 is an object. Numerals 2000 to 2005 indicate frames in which the same object was photographed. These pictures are often consecutive frames in a moving picture or still pictures photographed in such a manner that the camera was so moved that the photographic ranges may overlap with each other.

In FIG. 35B, numeral 2007 indicates a panorama picture obtained by combining these input pictures.

At step S1901, the individual object regions

existing in the resulting panorama picture are approximated using figures. The panorama picture formation at step S1900 and the figure approximation of the object region at step S1901 may be reversed in order. Depending on conversion in forming a panorama picture, the type of approximate figure for the object region may have to be changed. For example, in a case where the object region is approximated using a rectangle, when a panorama picture is formed by affine transformation, the resulting object region is not necessarily a rectangle. In this case, a panorama picture is formed earlier. Alternatively, the formed panorama picture is converted and the converted picture is modified.

At step S1902, the representative points or characteristic points of an approximate figure for the object region obtained at step S1901 are approximated using a function. The trajectory of the object region is obtained by determining a reference object region and finding the amount of change in each object region on the basis of the reference object region. For example, in FIG. 35B, the object region 2008 of a first input image is used as a reference and changes in the object region following the reference one are made a trajectory 2009. In this example, the center of gravity of the object region is used as a representative point. The same holds true when a representative

There are two methods of determining the amount of change from the reference point: one method of using the difference from the reference point and the other method of using the difference from the preceding object region. The amount of change can be approximated using a function. A change from the reference point can be approximated using a motion model, such as a parallel/rotational movement or affine transformation, not using the movement of representative points or characteristic points. Then, the movement of the object is described as the trajectory of its conversion coefficient. In this case, too, the trajectory of the conversion coefficient is approximated using a function.

At step S1903, the parameter of the function that approximates the trajectory found at step S1902 is described according to the format of the aforementioned data structure.

The parameters used in forming a panorama picture from the individual input pictures can be described in the same manner, considering all the input pictures as object regions.

FIG. 38 shows panorama parameters added to the object region data. The parameters indicate a

coordinate system of the panorama picture using the
coordinates of the representative points in the
respective picture and a conversion coefficient from
the coordinate system of the respective frames to the
coordinate system of the panorama frame. Though the
location of the origin of the coordinate system may
freely set, it is assumed in this embodiment that the
origin is set to the bottom left corner of the frame.
The width and the length of the frames forming the
panorama picture are constant and known. Panorama flag
3601 shows whether or not the coordinate system of the
panorama picture is applied. If the flag is 0, the
coordinate system of the panorama picture is not used
(the bottom left corner of each picture is the origin).
If the flag is 1, the coordinate system of the panorama
picture is used (the coordinate of each picture is
converted into that of the panorama picture). Model
type M 3602 shows a conversion from the each frame to
the panorama picture. The flag indicates no conversion
if it is 0, translation if it is 2, rotation/scaling if
it is 4, affine conversion if it is 6, perspective
conversion if it is 8, and quadratic conversion if it
is 12. The number of parameters of each model equals
to the number of model types M.

Translational model:

$$v_x(x, y) = a_1$$

$$v_y(x, y) = a_2$$

Rotation/scaling model:

$$v_x(x, y) = a_1 + a_3x + a_4y$$

$$v_y(x, y) = a_2 - a_4x + a_3y$$

Affine model:

5 $v_x(x, y) = a_1 + a_3x + a_4y$

$$v_y(x, y) = a_2 + a_5x + a_6y$$

Perspective model:

$$v_x(x, y) = (a_1 + a_3x + a_4y) / (1 + a_7x + a_8y)$$

$$v_y(x, y) = (a_2 + a_5x + a_6y) / (1 + a_7x + a_8y)$$

10 Quadratic model:

$$v_x(x, y) = a_1 + a_3x + a_4y + a_7xy + a_9x^2 + a_{10}y^2$$

$$v_y(x, y) = a_2 + a_5x + a_6y + a_8xy + a_{11}x^2 + a_{12}y^2$$

15 The origin for conversion is defined as
X-coordinate 3603 and Y-coordinate 3604 which are
represented by the coordinate system of the respective
pictures. The provision of origin for conversion makes
the conversion error small. Number of conversion
20 parameters N 3605 equals to the number of frames in the
panorama picture. Frame interval time period 3606 is
counted from the first frame. Set of parameters 3607
describes the M number of parameters depending on the
model type. The trajectory of the object of each frame
25 is described using this set of parameters.

When shooting is done, while the camera is
following the object region, a panorama picture is

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formed by mosaicking, whereby consecutive frames are image-transformed and then tied together. Describing the object region information on the formed image makes it possible to describe the object region information uniquely in a coordinate system with a certain point on the mosaicking image as a cardinal point, even when the camera is moving.

The second, third, fourth, and fifth embodiments are described in connection with the first embodiment in which the object region data is described using the differential vector of the representative points of the approximate figure. However, these embodiments for adding the depth information, display flag, passing range information, and panorama conversion parameters for mosaicking can be freely applied to any type of object region data. The following description will be focused on the variation of the object region data. Though the embodiments related to the combination of the depth information and object region data of other types will be described, it will be understood that the display flag, passing range information, and panorama conversion parameters for mosaicking can be applied to the object region data of the other types.

Sixth embodiment

In the sixth embodiment, the depth information is added to the object region data which is described using the trajectory of the coordinates of the

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The configuration of the object region data creating apparatus of the sixth embodiment is the same as that of the first embodiment shown in FIG. 1.

5 Though the object region is approximated using the polygon in the first embodiment, the object region is approximated using an ellipse in the sixth embodiment, as shown in FIGS. 39A to 39D. FIGS. 39A to 39D correspond to FIGS. 3A to 3C of the first embodiment.

10 The region is approximated with an ellipse by extracting two focal points v_1 and v_2 of the ellipse and one point v_3 on the ellipse and the representative point trajectory curve is approximated with a spline function.

15 FIG. 40 shows an example of the method of obtaining an approximate ellipse when the object region is expressed by a parallelogram. Points A, B, C and D shown in FIG. 40 are vertices of the parallelogram which is the object region. Calculations are performed

20 so that which side AB or side BC is a longer side is determined. Then, a smallest rectangle having portions of its sides which are the longer side and its opposite side is determined. In the case shown in FIG. 40, a rectangle having four points A, B', C and D' is

25 the smallest rectangle. The approximate ellipse is a circumscribing ellipse similar to the ellipse inscribing the rectangle and passing the points A, B',

C and D'.

Referring to FIG. 39B, reference numerals v1, v2, and v3 represent representative points of a figure expressing an ellipse. Specifically, the representative points v1 and v2 are two focal points of the ellipse and one point v3 on the same (one point on the minor axis in the case shown in FIG. 39B). The focal points of the ellipse can easily be determined from points on the two axes or a circumscribing rectangle of the ellipse. An example will now be described with which focal points F and G are determined from two points P₀ and P₁ on the major axis and point H on the minor axis shown FIG. 41.

Initially, a and b which are parameters of the major axis and the minor axis, center C of the ellipse and eccentricity e are determined as follows:

$$E(P_0, P_1) = 2 \times a$$

$$C = (P_0 + P_1)/2$$

$$E(C, H) = b$$

$$e = (1/a) \times \sqrt{(a \times a - b \times b)}$$

where E(P, Q) is the Euclidean distance between the point P and the point Q. In accordance with the determined parameters, the focal points F and G can be determined as follows:

$$F = C + e \times (P_0 - C)$$

$$G = C - e \times (P_0 - C)$$

Thus, the representative points F, G and H of the

ellipse are determined. When the foregoing points are made to correspond to the representative points of the ellipse extracted in another frame, ambiguity is involved. That is, two combinations exist which make the two extracted focal points correspond to the two focal points in the previous frame. Since two interdevices exist between the minor axis and the ellipse, the interdevice corresponding to the one point on the ellipse extracted in the previous frame cannot be determined. A method of determining the combination and the interdevice will now be described.

An assumption is made that the two focal points extracted in the previous frame are F_p and G_p . To determine F or G which correspond to F_p , the following comparison is made:

$$E((G_p - F_p)/2, (G - F)/2) \text{ and}$$

$$E((G_p - F_p)/2, (F - G)/2)$$

When the former focal point is smaller, F_p is made to correspond to F , and G_p is made to correspond to G . When the latter focal point is smaller, F_p is made to correspond to G and, G_p is made to correspond to F .

An assumption is made that the interdevices between the minor axis and the ellipse in the previous frame are H_p and the interdevices between the minor axis of the ellipse in the present frame are H and H' . The point H or H' which must be made to correspond to H_p is determined by calculating two distances:

$$E = (H_p - (G_p + F_p)/2, H' - (F + G)/2)$$

5 Note that the interdevice H between the minor axis and the ellipse in the first frame may be either of the two interdevices.

The representative points extracted by the foregoing process are usually varied in the position among the successive frames owing to movement of the object of interest in the video or shaking of the image pick-up camera. Therefore, the corresponding representative points of the ellipses are time-sequentially arranged to perform approximation with a spline function for each of the X and Y axes. In this embodiment, each of the three points F, G and H (see FIG. 41) which are the representative points of the ellipse requires a spline function for the X- and Y-coordinates. Therefore, six spline functions are produced.

The process which is performed by the

representative point trajectory function approximating device 104 may be carried out whenever the coordinates of the representative points of each frame relating to the object region are obtained. For example, the approximation is performed whenever the coordinates of the representative points in each frame are obtained. Moreover, an approximation error is obtained to arbitrarily divide the approximation section in such a manner that the approximation error satisfies a predetermined range. Another method may be employed with which the process is performed after the coordinates of the representative points in all of the frames relating to the object region have been obtained.

Reference numeral 203 shown in FIG. 39C represents the approximated spline function expressed three-dimensionally. Reference numeral 204 shown in FIG. 39D represents an example of the spline function which is the output of the representative point trajectory function approximating device 104 (only one axis of coordinate of one representative point is shown). In this example, the approximation section is divided into two sections (the number of knots is three) which are $t = 0$ to 5 and $t = 5$ to 16.

The thus-obtained spline functions are recorded in the region data storage device 106 in a predetermined data format.

As described above, this embodiment enables the object region in a video to be described as the parameter of a curve approximating a time-sequential trajectory (a trajectory of the coordinates of the representative points having the variable are the frame numbers or the time stamps) of the representative points of the approximate figure of the object region.

The object region in a video can be expressed by only the parameters of the approximate function. Therefore, object region data, the quantity of which is small and which can easily be handled, can be created. Also extraction of representative points from the approximate figure and determination of parameters of the approximate curve can easily be performed. Moreover, reproduction of an approximate figure from the parameters of the approximate curve can easily be performed.

A method may be employed with which a basic figure, for example, one or more ellipses are employed as the approximate figures and each ellipse is represented by two focal points and another point. In the foregoing case, whether or not arbitrary coordinates specified by a user exist in the region (the approximate figure) of the object (whether or not the object region has been specified) can be determined by a simple determinant. Thus, specification of a moving object in a video can furthermore easily be

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the object in the video may be the trailing end frame number. The leading/trailing end time stamp may be substituted for the lading/trailing end frame number. The object existence frame number or object existence
5 time may be substituted for the trailing end frame number 402B.

A pointer (hereinafter called a "related information pointer") 403B for related information is the address or the like of the data region in which data of
10 information related to the object having the foregoing ID number. When the related information pointer 403B is used, retrieval and display of information related to the object can easily be performed. The related
15 information pointer 403B may be pointer for pointing data of description of a program or the operation of a computer. In the foregoing case, when the object has been specified by a user, the computer performs a predetermined operation.

Note that the related information pointer 403B may
20 be omitted when the objects are not required to perform individual operations.

It is not necessary to have the related information pointer 403B. As an alternative to using the pointer 403B, related information itself may be
25 described in the object region data. Further, it is possible to have the related information pointer 403B or the related information itself in the object region

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The number of approximate figures 404B is the
5 number of the figures approximating the object region.
In the example shown in FIG. 39A in which the object
region is approximated with one ellipse, the number of
the figures is 1.

Note that approximate figure data 405B exists by the number corresponding to the number of approximate figures 404B (a case where the approximate figure number 404B is two or larger will be described later).

FIG. 43 shows the structure of approximate figure data 405B (see FIG. 42).

The number of representative points 1301B

FIG. 44 shows an example of the structure of representative point trajectory data 1302B, 1303B,

and 1304B.

A knot frame number 1400B indicates the knot of the spline function. Thus, a fact that polynomial data 1403B is effective to the knot is indicated.

5 The number of coefficient data 1402B of the polynomial varies according to the highest order of the spline function (assuming that the highest order is K , the number of coefficient data is $K + 1$). Therefore, reference to a polynomial order 1401B is made.

10 Subsequent to the polynomial order 1401B, polynomial coefficients 1402B by the number corresponding to the polynomial order ($K + 1$) follows.

Since the spline function is expressed in an individual polynomial between the knots, the
15 polynomials are required by the number corresponding to the number of knots. Therefore, data 1403B including the knot frame number 1400B and the coefficient of the polynomial 1402B is described repeatedly. When the knot frame number is the same as the trailing end frame
20 number, it means the last polynomial coefficient data. Therefore, termination of representative point trajectory data can be understood.

FIG. 43 shows that the depth information is described for each of the representative points.

25 However, it is possible to describe the depth information for each of the object region as shown in FIG. 17 in the second embodiment. FIG. 45 shows the

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object region data having one depth information for one
object region data. The approximate figure data
includes a depth information 1306B in addition to the
figure type ID 1300B, representative point number
1301B, and a pair of representative point trajectory
data 1302B and 1303B.

A case will now be described in which a figure
except for the ellipse is employed as the approximate
figure.

FIG. 46 is diagram showing the representative
points in a case where a parallelogram is employed as
the approximate figure. Points, A, B, C and D are
vertices of the parallelogram. Since three points of
the four vertices are determined, the residual one is
determined. Therefore, three vertices among the four
vertices are required to serve as the representative
points. In the foregoing example, three points, which
are A, B and C, are employed as the representative
points.

The examples have been described with which one
figure is assigned to one object to roughly approximate
the object region. The accuracy of approximation may
be improved by approximating one object region with
a plurality of figures. FIG. 47 shows an example in
which a plurality of figures approximate one object
region. In the foregoing case, a region of a person in
the image is expressed with 6 ellipses 600B to 605B.

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When one object is approximated with plural figures as shown in FIG. 47, a process for dividing the object region into a plurality of regions must be performed. The process may be performed by an arbitrary method. For example, a method with which the object is directly divided with manpower may be employed. In the foregoing case, a pointing device, such as a mouse, is used to, on the image, enclose the region with a rectangle or an ellipse. Alternatively, the region is specified with a trajectory of the pointing device. When an automatic method is employed as a substitute for the manpower, a method may be employed with which clustering of movement of the object is performed to realize the division. The foregoing method is a method with which the movement of each region in the object among the successive frames is determined by a correlation method (refer to, for example, Image Analysis Handbook Chapter-3, Section II, Publish Conference of Tokyo University, 1991) or a method with gradient constraints (refer to, for example, Determining optical flow, B. K. P. Horn and B. G. Schunck, Artificial Intelligence, Vol. 17, pp. 185-203, 1981) to collect similar movements to form a region.

Each of the divided regions is subjected to the above process so that data of the approximate figure is created. In the foregoing case, the spline function,

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which must be described in object region data of one object increases as the number of the approximate figures increases. Therefore, the structure of data is formed which includes approximate figure data 405B by the number (L in the foregoing case) corresponding to the approximate figure number 404B, as shown in FIG. 48.

As described above, the field for the approximate figure number 404B may be omitted by making the approximate figure number to always be one (therefore, data of the approximate figure is made to always be one) to the object region data. In the foregoing case, one object can be expressed with a plurality of figures when object region data is produced for each figure approximating one object (the same ID number is given).

When one object is approximated with a plurality of figures in this embodiment, the same figure is employed. A mixture of a plurality types of figures may be employed to approximate the object region.

Although the method of approximation using the ellipse has been described, an approximation method using a rectangle will now be described as another approximation method.

FIGS. 49A, 49B, and 49C are diagrams formed into the same shape as that of FIGS. 39A, 39B, and 39C. In the foregoing case, the region figure approximating device 102 employs a method of approximating a region

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with a rectangle. The representative point extracting device 103 employs a method of extracting the four vertices of the rectangle. The representative point trajectory function approximating device 104 employs an approximation method using a spline function.

Referring to FIG. 49A, reference numeral 2800B represents video data for one frame which is to be processed.

Reference numeral 2801B represents an object region which is to be extracted. A process for extracting the region 2801B of the object is performed by the region extracting device 101.

Reference numeral 2802B represents a result of approximation of the object region with the rectangle. The process for obtaining the rectangle 2802B from the object region 2801B is performed by the region figure approximating device 102.

An example of the process for obtaining the rectangle 2802B shown in FIG. 49A is shown in FIG. 50. That is, a mask image of the frame 2800B is raster-scanned (step S60B). When the subject pixel is included in the object region (step S61), the minimum value is updated if each of the X- and Y-coordinates is smaller than the stored minimum value. If the values are larger than the maximum value, the maximum value is updated (step S62B).

The foregoing process is repeated and checked for

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all of the pixels so that the minimum and maximum values of the pixel position indicating the object region 2801B for each of the X- and Y-coordinates are obtained. Thus, the coordinates of the four vertices
5 of the rectangle 2802B can be obtained.

Although the above-mentioned approximating method using the rectangle is excellent in easiness of the process, it is sometimes desirable to approximate the object region with the ellipse. FIG. 51 shows that
10 an approximate ellipse is obtained from the rectangle representing the object region. FIG. 52 shows the process of obtaining the approximate ellipse.

Referring to FIG. 51, it is assumed that an object region 3300B and a circumscribing rectangle 3301B have
15 been obtained.

Initially, the inscribing ellipse and the circumscribing ellipse of the approximate rectangle 3301B are obtained (step S80B).

Referring to FIG. 51, an ellipse 3302B is an
20 inscribing ellipse of the rectangle 3301B and the ellipse 3303B is a circumscribing ellipse of the rectangle 3301B.

Then, the size of the inscribing ellipse 3302B is gradually brought closer to that of the circumscribing ellipse 3303B (step S81B). Then, an ellipse 3304B for
25 completely including the object region 3300B is obtained (step S82B) to employ the ellipse 3304B as the

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approximate ellipse. The unit for enlarging the size of the inscribing ellipse 3302B in each process of the repeated process may previously be determined. The unit may be determined in accordance with the difference between the size of the inscribing ellipse 3302B and that of the circumscribing ellipse 3303B.

A reverse method may be employed with which the size of the circumscribing ellipse 3303B is brought closer to the size of the inscribing ellipse 3302B. In the foregoing case, the circumscribing ellipse 3303B includes the object region 3300B from the first. Therefore, the ellipse previous to the ellipse with which the portion which is not included in the object region 3300B has first occurred in the repeated process is required to be the approximate ellipse 3304B.

An example will now be described in which when a trajectory of the object region is described by the method According to embodiments of the present invention, the structure of data which is different from the approximate data structure shown in FIGS. 42 and 43 is employed.

FIGS. 52 and 53 show another example of a description format for data of the approximate figure and data of trajectories of representative points of the object region. Note that FIGS. 52 and 53 shows only one representative point for a section (section from knot number N 3902B to a function specifying

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Description will now be made on the assumption that the highest order of the polynomial is the second order.

The foregoing description method will now be described.

The figure type ID 3900B shown in FIG. 53 specifies the type of the figure which has been used to approximate the shape of an object. For example, only the centroid, the rectangle, the ellipse or their combination can be specified. The number of representative points 3901B indicates the number of the trajectories of the representative points which are determined in accordance with the type of the figure.

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indicate the order of the polynomial spline function and information for specifying the coefficient of the polynomial spline function, respectively.

5 The number of function parameters 3914B, 3918B, and 3922B for X-, Y-, and Z-coordinates are (knot number - 1) so that they are described as the arrangements 3915B, 3919B, and 3923B.

10 Although the description has been made that the highest order of the polynomial is the quadratic order, the highest order of the polynomial may, of course, be a cubic or higher order.

15 FIGS. 52 and 53 show that the depth information is described for each of the representative points. However, it is possible to describe the depth information for each of the object region as shown in FIG. 17 in the second embodiment. FIGS. 54 and 55 show the object region data having one depth information for one object region data.

20 FIG. 55 shows the object region data having the figure type ID 700B, object appearing time 701B, object existing time period 702B, number of representative points M 703B, representative point trajectory 704B, and depth information 705B, in the same manner as FIG. 8. FIG. 56 shows the representative point
25 trajectory 704B which is obtained by excluding the figure type ID 3900B, representative point number 3901B, arrangement of knot Z 3910B, and arrangement of

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function specifying information Z 3923B.

Though the sixth embodiment adds the depth information to the object region which is described using the trajectory of the coordinates of the representative points of the approximate figure, it is possible to add the display flag, passing range information, and panorama conversion parameters for mosaicking to the above described object region data.

Seventh embodiment

In the seventh embodiment, the depth information is added to another object region data. The object region data in an arbitrary frame of the seventh embodiment is described by a reference object region data in a reference frame and a conversion parameter indicating the conversion from the reference object region to an object region in the arbitrary frame.

The configuration of the object region data creating apparatus of the seventh embodiment is shown in FIG. 57. The object region data creating device comprises a video data storage device 2C, object region processing device 4C, conversion parameter calculation device 6C, function approximation device 8C, and object region data storage device 10C.

The video data storage device 2C stores video data. The device 2C is constituted by, for example, a hard disk device, an optical disk device or a semiconductor memory. It is noted that the video data

5 The object region processing device 4C executes
a processing for obtaining an object region in a frame
serving as a reference (reference object region) and
an object region in a frame serving as a target (target
object region).

15 The function approximation device 8CC executes
a processing for approximating a time series trajectory
by a temporal function for each conversion parameter of
the object region. As will be described later, if the
conversion parameters themselves are described, this
function approximation device 8C is not necessary.

Although it is preferable that the reference
object region is updated, a device relating to
the update processing is not shown in FIG. 57.

The video data storage device 2C and the object region data storage device 10C may be constituted by

5 This object region data creating apparatus can be
also realized by executing a software on a computer.

First, in step S101C, object regions in all frame
10 in a video are inputted (while assuming that object
regions are known). If the object regions are manually
input through GUI, the contour of an object serving
as a processing target in the video is specified by
a pointing device such as a mouse or a touch panel.
15 The interior of the contour of the object inputted
manually may be set as an object region. Alterna-
tively, after fitting an inputted contour to the
contour line of the object in an image by means of
a technique using a dynamic outline model referred to
20 as Snakes (see, for example, M. Kass, A. Witkin and
D. Terzopolus, "Snakes: Active contour models",
Processings of the 1st International Conference on
Computer Vision, pp. 259-268, 1987), the interior of
the contour thus fitted may be set as an object region.
25 Instead of manually inputting the contour, object
regions may be obtained automatically by executing
an image processing. If data relating to the object

regions are already present, it is possible to input such data.

At least one of these object regions is registered as a reference object region. To register the object region, there is proposed a method including generating and storing a binary bit map on which "1" corresponds to the interior of each object region and "0" corresponds to the outside of the region.

Further, a frame including the reference object region is registered as a reference frame.

Next, in step S102C, a conversion parameter for converting the reference object region into an object region in one frame serving as a processing target (to be referred to as "target object region" hereinafter) is calculated.

This processing can be realized by a combination of, for example, a processing for calculating an optical flow in the target object region and a processing for converting the optical flow into the conversion parameter. The processing for calculating an optical flow in the target object region is to calculate the movement (optical flow) of each pixel (or a block formed of a plurality of pixels) in the object region from the reference frame to a present frame.

FIG. 59 shows the schematic of a processing example for obtaining an optical flow in the object region in each frame.

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In FIG. 59, reference symbol 201C denotes a reference frame, 202C denotes the next frame to the reference frame, and 203C denotes the next frame to the frame 202C. Reference symbols 204C, 205C and 206C denote object regions in the respective frames. Reference symbol 207C denotes the optical flow of the object region from the frame 201C to the frame 202C. Reference symbol 208C denotes the optical flow of the object region from the frame 201C to the frame 203C.

As can be seen, the optical flow obtaining method can directly associate the reference object region with an object region in an arbitrary frame. This facilitates procedure for calculating an object region in an arbitrary frame and for determining whether a specified coordinates indicate the interior or the exterior of the object.

In the example of FIG. 59, the optical flow of each pixel (or each block formed of a plurality of pixels) in the object region from the reference frame to the current frame is obtained. Alternatively, the optical flow of each pixel (or each block formed of a plurality of pixels) in the object region from one frame before the current frame and the current frame may be obtained. FIG. 60 shows the schematic of a processing example in the latter case.

In FIG. 60, reference symbol 301C denotes a reference frame, 302C denotes the next frame to

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the reference frame, and 303C denotes the next frame to the frame 302C. Reference symbols 304C, 305C and 306C denote object regions in the respective frames. Reference symbol 307C denotes the optical flow of the object region from the frames 301C to 302C. Reference symbol 308C denotes the optical flow of the object region from the frame 302C to 303C.

If calculating optical flows as shown in FIG. 60, parameter variations becomes smaller than those in the method of FIG. 59. However, the calculation of the object region in an arbitrary frame is more complex than the method of FIG. 59. While either the method shown in FIG. 59 or that shown in FIG. 60 may be employed, description will be continued while assuming that the optical flow is calculated by the method shown in FIG. 59 in this embodiment.

Many methods for obtaining an optical flow have been already proposed (see, for example, J. L. Barron, D. J. Fleet and S. S. Beauchemin, "Performance of Optical Flow Techniques", International Journal of Computer Vision, vol. 12, no. 1, pp. 43-77, 1994). It is possible to adopt any method to obtain an optical flow.

It is also possible to select a plurality of characteristic points in the reference object region and to use a moving vector obtained by template matching with blocks centered around the characteristic

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points used as a template.

Next, a processing for calculating a conversion parameter from an optical flow is executed. It is noted that a conversion parameter to be obtained varies according to conversion models which the parameters are based on.

In this embodiment, the following models can be selected:

"Enlargement/reduction model" and "Rotation model" as models when the number of parameters is 1;

"Parallel translation model" as a model when the number of parameters is 2;

"Composite model of enlargement & reduction/rotation/parallel translation models" (to be referred herein as "4-parameter conversion model") as a model when the number of parameters is 4;

"Affine conversion model" as a model when the number of parameters is 6;

"Projection conversion model" as a model when the number of parameters is 8; and

"Parabolic conversion model" as a model when the number of parameters is 12.

The respective models are expressed by the following mathematical formulas (1) to (7):

$$x' = a_0x,$$

$$y' = a_0y \quad (1)$$

$$\begin{aligned}x' &= x \cos a_0 - y \sin a_0, \\y' &= x \sin a_0 + y \cos a_0\end{aligned}\tag{2}$$

$$\begin{aligned}x' &= x + a_0, \\y' &= y + a_1\end{aligned}\tag{3}$$

$$\begin{aligned}x' &= a_0x + a_1y + a_2, \\y' &= a_1x - a_0y + a_3\end{aligned}\tag{4}$$

$$\begin{aligned}x' &= a_0x + a_1y + a_2, \\y' &= a_3x + a_4y + a_5\end{aligned}\tag{5}$$

$$\begin{aligned}x' &= (a_0x + a_1y + a_2) / (a_3x + a_4y + 1), \\y' &= (a_5x + a_6y + a_7) / (a_3x + a_4y + 1)\end{aligned}\tag{6}$$

$$\begin{aligned}x' &= a_0x^2 + a_1xy + a_2y^2 + a_3x + a_4y + a_5, \\y' &= a_6x^2 + a_7xy + a_8y^2 + a_9x + a_{10}y + a_{11}\end{aligned}\tag{7}$$

The mathematical formula (1) corresponds to the enlargement and reduction model, the mathematical formula (2) corresponds to the rotation model, the mathematical formula (3) corresponds to the parallel translation model, the mathematical formula (4) corresponds to the 4-parameter conversion model, the mathematical formula (5) corresponds to the Affine conversion model, the mathematical formula (6) corresponds to the projection conversion model, and the mathematical formula (7) corresponds to the parabolic conversion model. In the formulas, (x, y) denotes coordinates in the reference object region, and (x', y') denotes the coordinates of the corresponding point of the object in the target object region. In the respective conversion models, it is assumed

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that the relationship between corresponding points in the two frames can be expressed using parameters a_0 to a_{11} as shown in the formulas. Needless to say, a parametric model other than the above-described models may be prepared.

To calculate the conversion parameter, a method of least squares can be employed. This method is to determine the conversion parameter so that the sum of the squares of an error generated when a combination of (x, y) and (x', y') obtained by optical flow are substituted into the conversion model mathematical formula may become a minimum. This is an old, conventional method and can be easily executed by matrix operation.

Next, in step S103C, the calculated conversion parameter of the object region is converted to (approximated by) a temporal function.

Namely, "n" number of conversion parameters a_i ($0 \leq i \leq n-1$) (e.g., $n = 12$) in a certain time interval are expressed by:

$$a_i = f_i(t),$$

where $f_i(t)$ is the function of time t .

The time interval here is one including the frames for which an optical flow is calculated using the same reference object region. $f_i(t)$ may be a polynomial, a Spline function, a constant or the like.

FIG. 61 shows a state in which a certain

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conversion parameter a_i calculated from the optical flow is expressed by a function. In FIG. 61, reference symbol 401C denotes a time interval in which a function is to be obtained, 402C denotes a value of a_i calculated from the optical flow, and 403C denotes a function $a_i = f_i(t)$ expressing the parameter a_i .

The advantage of expressing parameter a_i by a function is that the quantity of data for describing object regions can be reduced. If a polynomial of second degree or lower is used as a function, for example, three real numbers suffice to describe all parameter values in a certain time interval since this function can be expressed by three real numbers.

If a polynomial or a spline function is used as a function expressing the conversion parameter, the conversion parameter a_i is determined so that the error between the values of a_i in the conversion target time interval and the values calculated by the function $f_i(t)$ may become small. By using, for example, the method of least squares, the parameter can be easily calculated.

This processing for obtaining an approximate function may be executed every time parameter values relating to the object region in each frame are obtained (e.g., a method of executing approximation and obtaining an approximate error every time parameter values in each frame are obtained, and appropriately

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To make this determination, it is possible to employ a method of determining whether or not the error

between an actual object region in a certain frame and a predicted object region exceeds a preset threshold value. The predicted object region means an object region in a certain frame which is calculated from the reference object region by using the conversion parameter. The conversion parameter used for conversion is a value calculated from the temporal function $a_i = f_i(t)$. As the error between the actual object region and the predicted object region, a ratio of the area of a common portion to both regions to the area of a part which is not common can be used.

Next, in step S105C, if it is determined at step S104C that it is necessary to update the reference object region, a reference object region update processing is executed. This processing is basically the same as the processing executed in step S101C. That is to say, in the processing in step S105C, the processing target frame for which the conversion parameter is calculated in step S102C is registered as a reference frame, and a binary bit map expressing the reference object region are generated. Further, an object region in the reference frame is registered as a reference object region.

In step S106C, it is determined whether or not a processing for describing the object regions in the video is ended. This determination is based on, for example, whether or not a current object region is at

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the final frame of the video, whether or not a current object region is at the final frame of an object region existing time-interval, whether or not a user indicates the end of the description processing or the like.

5 The processings from steps S102C to S104C or S105C are repeatedly executed for each frame until it is determined that the description processing is ended in step S106C.

10 In step S107C, information on the description of the object region (parameter of the function approximating conversion parameter) calculated by the preceding processings is recorded according to a predetermined description format. The information is recorded by the object region data storage device 10C
15 such as, for example, a semiconductor memory inside or outside of a computer, a magnetic tape, a magnetic disk or an optical disk.

FIG. 62 shows one example of an object region description format with respect to one object region in
20 this embodiment.

In FIG. 62, reference symbol 501C denotes an object ID which is identification information (e.g., number or symbol) allotted to and peculiar to an object.

25 Reference symbol 502C denotes the number of constant reference object region time-intervals which is the number of frame intervals having the same

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reference object region (N in FIG. 62). This number N is also equal to the number of reference frames.

Reference symbols 503C and 504C denote a start time and an end time of object region existing time-intervals, respectively. Each time is described by time itself or frame number. The length of the object region existing time-interval (a subtraction value of time or frame number) may be used instead of the end time.

Reference symbol 505C denotes object region description information. The object region description information 505C is described for each reference object region interval, i.e., by the number of the constant reference object region time-intervals (N in the example of FIG. 62). Reference symbol 512C denotes a depth information for the object which is the same as FIG. 18.

The concrete contents of each object region data description information 505C are indicated by reference symbols 506C to 510C shown in FIG. 62.

The reference symbols 506C and 507C denote a start time and an end time of the reference object region interval, respectively. Each time is described by a time itself or a frame number. The length of the reference object region interval can be used instead of the end time.

The reference symbol 508C denotes a conversion

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model ID. This is intended to specify which model, such as the enlargement and reduction model, the affine conversion model and the parabolic conversion model, is used to describe the object region.

5 Reference symbol 511C denotes the coordinates of an origin to determine where the coordinates of the origin of the conversion model is positioned in an image. The origin coordinate data can be omitted if such a rule as to set the position of the center of gravity of the reference object regions to be
10 constantly at an origin, is predetermined.

 The reference symbol 509C denotes reference object region data to specify a reference object region. To be specific, the reference object region data
15 include the time of the reference frame (or frame number), bit map data representing the reference object regions (or a pointer to the bit map data). It is preferable that the bit map data is compressed and then stored since the data size is large unless compressed.

20 The reference symbol 510C denotes conversion parameter information. The conversion parameter information are described by the number of parameters (M parameters in the example of FIG. 62) set by a conversion model (conversion model ID). To be
25 specific, the conversion parameters include an arrangement of parameter values in each frame, information for specifying an approximate function

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of the parameters (coefficient values) and the like.
The conversion parameter information will be described
later in detail.

By executing the above-described processings, the
5 object regions changing spatially and/or temporally in
the video can be recorded, as simple description data.

In the above description, the object region is
expressed by the bit map, and the conversion parameter
for converting the reference object region into an
10 object region in the processing target frame (target
object region) is calculated. However, it is possible
to approximate an object region with an approximate
figure and calculate a conversion parameter for
converting the respective representative points of
15 the approximate figure of the reference object region
into the corresponding representative points of an
approximate figure of an object region in a processing
target frame (target object region).

FIG. 63 shows an example of the constitution of
20 an object region data creating apparatus. The object
region data creating apparatus comprises the video data
storage device 2C, object region processing device 4C,
a figure approximation device 5C, the conversion
parameter processing device 7C, function approximation
25 device 8C, and object region data storage device 10C.
If processings executed by the creating apparatus are
intervened by the operation of a user, a GUI for

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embodiment.

A step S301C is the same as step S101C in FIG. 58.

In step S302C, object regions are approximated by preset figures throughout the interval in which object regions exist.

In the processing for approximating the object region by a figure, an approximate region as small as possible to surround the object region is found. As figure used for approximation, various figures such as a rectangle (a square, a rectangle), a parallelogram with or without gradient, an ellipse (including a circle) and a polygon with or without gradient, can be employed. In addition, as the region approximation method, various methods such as a method of approximating a region by a circumscribed figure of the region, a method of approximating a region by an inscribed figure of the region, a method of setting the center of gravity of the region to the center of gravity of an approximate figure, a method of making the areas of the region and the approximate figure equal and a method of minimizing the area of a portion on which the region and an approximate figure do not overlap each other, may be employed.

Instead of approximating the object region to a preset figure, the type of a figure can be specified by a user for each target object. Alternatively, the type of a figure can be automatically selected according to

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the shape or the like of the object for each target object.

Furthermore, the processing for obtaining the approximate figure of the object region may be executed for each frame or executed by object regions in several frames before and after the target frame. In the latter case, the changes of the size and position of the approximate figure are smoothed among several frames, thereby making it possible to smooth the movement or deformation of the approximate figure or to make the extraction error of the object region inconspicuous. It is noted that the size of the approximate figure may vary according to the frame.

If the approximate figure of the object region is obtained, a processing for extracting representative points expressing this approximate figure is executed. Which points are used as representative points depends on which type of an approximate figure is used. If the approximate figure is, for example, a rectangle, four or three vertexes may be set at representative points. If the approximate figure is a circle, the center and one circumferential point or both end points of the diameter may be used as representative points.

Further, if the approximate figure is an ellipse, the vertexes of the circumscribed rectangle of the ellipse, or two focuses and one point on the ellipse (e.g., one point on the short axis of the ellipse) may be used as

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representative points. If the approximate figure is an arbitrary closed polygon, it is necessary to use the respective vertexes of the polygon as representative points.

5 The representative points are extracted in units of frames every time an approximate figure for one frame is obtained. The respective representative points are expressed by a horizontal coordinate x and a vertical coordinate y .

10 A method of obtaining an approximate ellipse if the object region is expressed by a parallelogram is the same as that shown in FIG. 40.

A method of obtaining representative points from the ellipse is the same as that shown in FIG. 41.

15 The approximate figure is not limited to the ellipse but may be a parallelogram or a polygon.

Next, in step S302C, a reference object region and a reference frame are set. The reference object region is the approximate figure of an object region in the first frame (reference frame) in an object region existing time-interval. The positions of the representative points of the reference region approximate figure are stored, as well.

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Next, in step S303C, the representative points of approximate figure of the object region in a processing target frame are made to correspond to those of the approximate figure of the reference object region.

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FIG. 65 shows one example of how to make the former representative points correspond to the latter representative points. In FIG. 65, reference symbol 1000C denotes the centers of gravity of approximate rectangles. In FIG. 65, the approximate figure 1001C of the reference object region and the approximate figure 1002C of the target object region are obtained.

First, either the approximate figure 1001C or 1002C is moved in parallel, to thereby make the positions of the centers of gravity of the both figures 1001C and 1002C coincident with each other (FIG. 65 shows a state in which the positions of the centers of gravity are coincident with each other).

Thereafter, distances d1 to d4 between the four vertexes of the figure 1001C and those of the figure 1002C are calculated, respectively and the sums of the distances are obtained from all combinations of the vertexes.

Among them, a combination having the smallest sum of distances is obtained and the representative points of the combination are made to correspond to one another.

It is noted that there are cases where it is difficult to make the representative points of the approximate figure of the object region correspond to those of the approximate figure of the reference object region in this method. For example, if an approximate

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5 In FIG. 66, symbol \bigcirc denotes a combination capable of calculating parameters and symbol \times denotes a combination incapable of calculating parameters.

In step S306C, it is determined whether or not it is necessary to update the reference object region. In this processing, the reference object region is first converted by the conversion parameters and a predicted object region in a current frame is calculated. Needless to say, it is possible to calculate the same predicted object region by converting only the representative points of the reference object region using the conversion parameters and constituting a figure specified by the converted representative points. Next, the error between the predicted object region and the approximate figure of the target object region in the current frame is calculated and it is determined whether or not the reference object region needs to be updated by a threshold value.

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object region data will be described hereinafter.

In the above-described examples, conversion parameters are obtained for all frames with respect to a certain object region. Frames for which conversion parameters are obtained may be sampled. For example, one frame out of three frames may be sampled and a reference object region in frame 1 as well as reference object regions in frames, 4, 7, ... may be used.

If conversion parameters are expressed by a temporal function and information for specifying the function are described in object region data, then the object region data may be approximated by a function by the sampled parameter values as in the case of the above-described examples. In addition, it is not necessary to include information on sampling in the object region data.

Meanwhile, if conversion parameter values are directly described in the object region data, then (1) parameter values in the frames which are not sampled are appropriately interpolated (e.g., the same values as those in the frame which has been sampled just before the frame which is not sampled are described in the object region data) and the same object region data as that in FIG. 62 is prepared, or (2) sampling information 520C as shown in FIG. 68 is added to the object region data, only the parameter values in the sampled frames and information for allowing specifying

a sampling method (e.g., numeric value "n" as information indicating that n frames are sampled once (note, however, that in case of $n = 1$, for example, it is assumed that all frames are sampled)) may be described in the sampling information 520C in the first embodiment. In the method of (2), if using the object region data, parameter values in the frames which have not been sampled can be interpolated, if necessary, by referring to the sampling information 520C.

Next, description will be given to a method of generating object region data by dividing one object into a plurality of regions in the above described embodiments.

Conventionally, one conversion parameter is obtained for one object. In case of an object which apparent shape has great change, however, it is sometimes preferable to divide an object into a plurality of regions and use conversion parameters for the respective regions. For example, a walking person heavily moves his or her hands and legs although less moves his or hear head and body. In that case, it is possible to obtain conversion parameters for the respective parts in a stable manner by dividing the object into separate regions of head/body/hands/legs rather than dealing with the person as one object.

If one object is expressed by a plurality of figures, it is required to execute a processing for

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The example of FIG. 70 is to expand the data structure (FIG. 67) for describing the object in a single region and data following region ID data 2906C are the same as those in FIG. 67. The number of divided regions is stored in 2902C and data on the respective divided regions are held in 2905C and the following.

Though the seventh embodiment adds the depth information to the object region of an arbitrary frame which is described using a reference object region data in a reference frame and a conversion parameter indicating the conversion from the reference object region to the object region in the arbitrary frame, it is possible to add the display flag, passing range information, and panorama conversion parameters for mosaicking to the above described object region data.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the present invention in its broader aspects is not limited to the specific details, representative devices, and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents. While in each of the above embodiments, information that determines the approximate figure is used as the representative points of a figure approximating the object region,

a plurality of characteristic points extracted from the object region in the image may be used as the representative points of the figure. Various things can be considered as characteristic points. For instance, the angles of an object (for example, as described in L. Kitchen and A. Rosenfeld, "Gray-level corner detection," Pattern Recognition Letters, No. 1, 1982, pp. 95-102) and the center of gravity of an object may be considered. In this method, there is not enough information to determine an approximate figure. Consequently, it is impossible to determine an approximate figure itself from the object region data, but the processing at the upper-layer processing unit becomes simpler.

The data format of the object region data is similar to that in the case of the representative points. Only the approximate figure data is changed to characteristic point data, the number of the representative points to the number of the characteristic points, and the representative point trajectory to the characteristic point trajectory. The number of the approximate figures and the figure type IS are omitted.

The methods and apparatus of the present invention apply to a computer-readable recording medium in which a program is recorded that causes a computer to execute a procedure equivalent to the present invention (or to function as means equivalent to the present invention

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or to realize a function equivalent to the present invention).

According to embodiments of the present invention, the region of the target object in the video is described as the parameters of the function that approximates the trajectory obtained by arranging, in the direction of frame advance, the quantity indicating the position of the representative points of an approximate figure for the object region. This makes it possible to describe the region of the desired object in the image using a smaller amount of data and facilitates the creation and handling of the data.

Furthermore, According to embodiments of the present invention, it is possible to search for an object in the image efficiently and effectively.

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